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Design Prediction of TWT Collector using Data Science

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***Abstract*- A Multistage depressed collector (MDC) is a critical component of traveling wave tubes (TWT) and contribute major share of the TWT overall efficiency, and hence, needs special consideration in designing such MDC for very high efficiency TWT. In this paper, a data-driven approach to model high efficiency MDC has been presented. A series of spent-beam data has been generated from the beam-wave interaction software, SUNRAY and subsequently, the data has been analyzed using k-means clustering .The depressed electrode potentials obtained via data clustering, gave an efficiency of 82.8 %. This new approach is much faster then the conventional approach reported eslewhere.**

I. Introduction

The inclusion of a depressed collectors in electron tubes since its inception has undergone several evalution based on the application for efficiency enhancement in electron beam tubes [1], [2]. However, with the agility of high power, high gain, wide bandwidth, high efficiency, etc in TWT, modelling and simulation of MDC is becoming promising with the help of modern innovative design concepts and technological innovations .For efficiency enhancement, MDCs are modelled/ designed with respect to different shape, size and geometry of the electrodes and found that tilted electrode collectors (TEC) were the simplest to fabricate and give optimum efficiency [3]. In the TEC's the maximum efficiency is obtained when the particles are collected on electrodes that are positioned along a parabola as shown in figure 1, also called as the minimum velocity curve.

This is so, because such an arrangement of electrodes ensure soft landing of electrons, as at this position they are at their minimum velocity.

$$z = \alpha r^2 / 2v_r^2 \qquad (1)$$

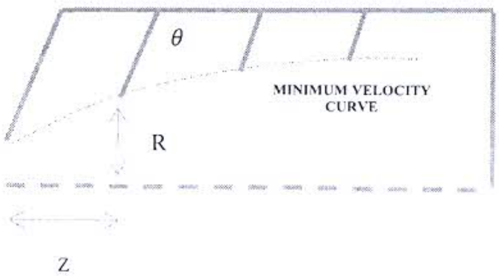

Figure 1. Schematic of a four stage symmetric multi stage depressed collector

These TECs, have been studied and anlaysed with various geometry variations, different material and applied magnetic field for improving their performance.

Voltage	V1	V2	V3	V4
Radial Position	R1	R2	R3	R4
Axial Position	Z1	Z2	Z3	Z4
Slope	$\theta 1$	$\theta 2$	$\theta 3$	$\theta 4$

Table 1 : Paramets to be optimized for a 4 stage TWT-MDC

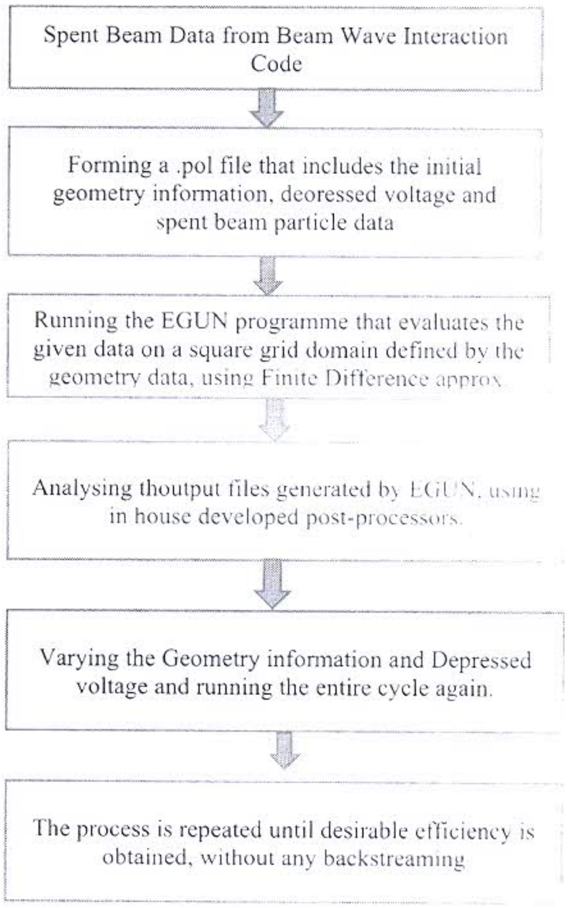

Figure 2. The conventional approach to optimize the parametrs of a collector using the trajectory follower code EGUN

The design methodology on the other hand, however has not seen any major change. The design procedure of a four-staged MDC requires following parametrs to be optimized, where Z_i is the distance of the i^{th} electrode-tip from origin and R_i is the radial distance of the i^{th} electrode-tip from the axis. θ_i is the tilt angle of the electrodes , respectively.*(i=1,2,3,4 ....n for a N stage MDC)*

Thus, the conventional process , depicted in figure 2, requires multiple iterations for convergent result, and does not confirm any absolute and optimum result. During multiple iteration, The result converges to a local optimum solution and moving towards the absolute maxima through many more set of cycles in EGUN code.

However, in the proposed Data Driven approach [4] ,the design knowledge can be extracted using smart search, that can operate on a multidimensional data. In this work we have clustered the data using k-means clustering. The data which was clustered was a six dimensional data having information of $r, \theta, z. \frac{dr}{dt}, \frac{d\theta}{dt}$ and $\frac{dz}{dt}$ for 96 particles.

The k-means clustering places the data in different clusters Each cluster is defined around a randomly picked data value called as the centroid. The centroid is then varied, and particles are displaced in another groups until the distance between data points and centroid , given by equation (2) ,is minimized.

$$dist = \sqrt{((z_c - z_n)^2 + (r_c - r_n)^2 + (\theta_c - \theta_n)^2 + (\dot{z}_c - \dot{z}_n)^2 + (\dot{r}_c - \dot{r}_n)^2 + (\dot{\theta}_c - \dot{\theta}_n)^2)} \quad (2)$$

In equation (2) , 'c' denotes the centroid value and n refers to the n^{th} particle.The centroid values are varied until no more particle is placed in another group.

III. RESULTS AND DISCUSSIONS

The four stage MDC was optimized in EGUN using conventional design approach. The same spent beam data was used to design MDC using theproposed data driven approach and summary of results are depicted in Table-2. The centroid obtained after crisp-clustering i,e, each particle belonging to a single cluster only without any overlap of each cluster , was used as the depressed voltage. The results of the efficiency are shown in figure 3 and figure 4, that have been generated by the in-house developed post-processor for EGUN.

The proposed methodology based on k-means clustering was found to be much faster then the conventioional iterative method. As shown in Table-3, it was also observed that the predicted electrode potentials are lower than those obtained from conventional approach and are close to practical value with improved efficiency.

METHOD	V1	V2	V3	V4	TIME	EFF.
ITERATIVE	-4410	-5120	-5880	-6900	>55 CYCLES	88.3%
DATA DRIVEN	-4052	-4698	-5326	-6855	PREDICTION IN ONE RUN	89.8 %

Table 2 : Comparison of the results from the conventional iterative method with the data driven method

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**************************************************************
*                  COLLECTOR ANALYSIS                        *
**************************************************************
* Total No. of Trajectories                 =     96         *
* Back-streaming Trajectories               =      0         *
* Total Power Entering the Collector        = 653.012 W      *
* Beam Current                              = 130.000 mA     *
* Back-streaming Current                    =   0.000 mA     *
* Power Recovered by the Collector          = 586.596 W      *
* Power Loss in the Collector               =  66.415 W      *
* Back-streaming Power                      =   0.000 W      *
* Collector Efficiency                      =    89.8 %      *
**************************************************************
*  Voltage  | No. of |  Current |  Pow. rec.  |  Pow. Loss   *
*    (V)    |  traj. |   (mA)   |    (W)      |    (W)       *
*-----------*--------*----------*-------------*--------------*
*       0   |    0   |   0.0    |   0.0       |   0.0        *
*   -4052   |   14   |  19.0    |  63.2       |   8.9        *
*   -4698   |   36   |  48.8    | 194.3       |  20.2        *
*   -5326   |   26   |  35.2    | 162.8       |  17.3        *
*   -6855   |   20   |  27.1    | 166.3       |  19.9        *
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Figure 3. The output of the EGUN postprocessor with the applies parametrs extracted using k-means clustering

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**************************************************************
*                  COLLECTOR ANALYSIS                        *
**************************************************************
* Total No. of Trajectories                 =     96         *
* Back-streaming Trajectories               =      0         *
* Total Power Entering the Collector        = 653.012 W      *
* Beam Current                              = 130.000 mA     *
* Back-streaming Current                    =   0.000 mA     *
* Power Recovered by the Collector          = 576.395 W      *
* Power Loss in the Collector               =  76.617 W      *
* Back-streaming Power                      =   0.000 W      *
* Collector Efficiency                      =    88.3 %      *
**************************************************************
*  Voltage  | No. of |  Current |  Pow. rec.  |  Pow. Loss   *
*    (V)    |  traj. |   (mA)   |    (W)      |    (W)       *
*-----------*--------*----------*-------------*--------------*
*       0   |    0   |   0.0    |   0.0       |   0.0        *
*   -4410   |   11   |  14.9    |  47.2       |   8.8        *
*   -5120   |   34   |  46.0    | 179.0       |  19.8        *
*   -5880   |   30   |  40.6    | 189.0       |  15.0        *
*   -6900   |   21   |  28.4    | 161.1       |  33.0        *
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Figure 4. The output of the EGUN postprocessor with the applied voltages using the conventional iterative method

III COCLUSION

A new method has been proposed for designing a Multistage Depressed collector. The proposed method is a much faster approach then the conventional iterative approach of designing a collector. The results obtained showed good efficiency and were found to more accurate. The method can be expanded to set up a data driven device modellig for Vacuum Electronic Devices, and can be used in parallel with the existing algorithms, to speed up the computational calculations based on the data prediction, which currently require long hours even after intensive computational platforms.

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